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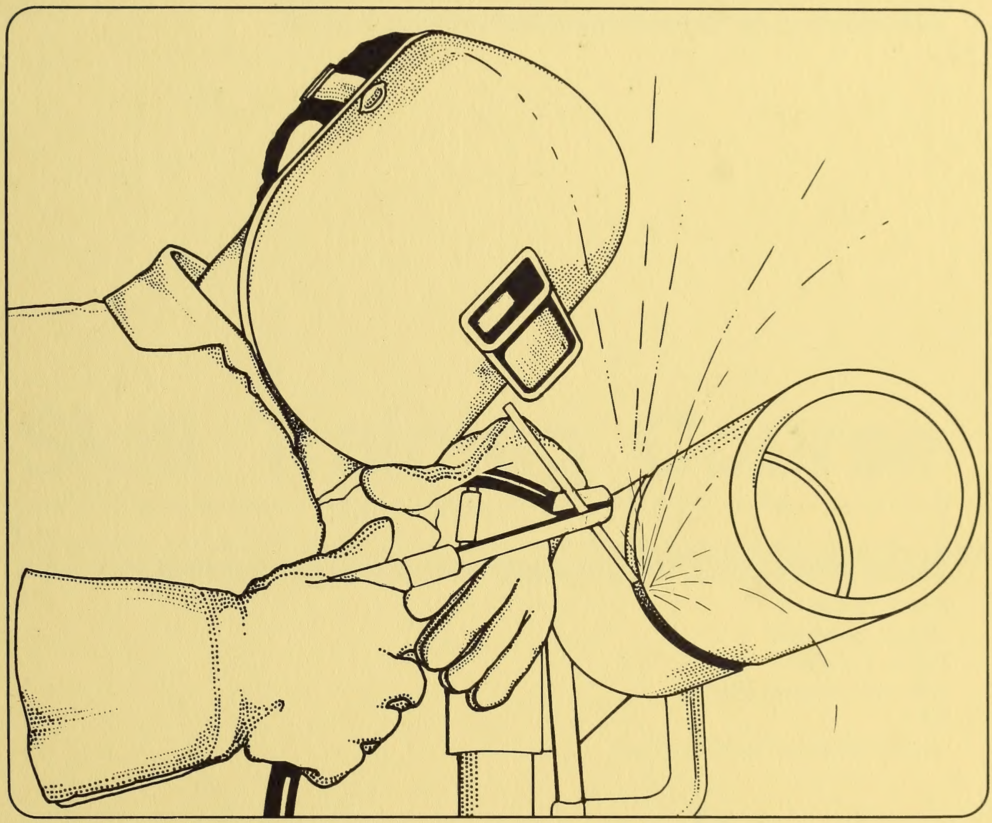
FARM WELDING



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FARM WELDING

INTRODUCTION

The need for welding on the farm increases as mechanization on the farm increases and in Alberta it is now common for farmers to do much of their own welding.

This booklet is designed to teach safe and proper farm welding techniques using oxy-acetylene or electric-arc equipment.

OXY-ACETYLENE WELDING THEORY

Description of Equipment

The oxygen cylinder is a drawn seamless steel bottle, having a wall thickness of about 8 mm (5/16 in.), the top and bottom being considerably thicker. When this cylinder is full of oxygen, it contains approximately 6,910 dm^3 (244 $ft.^3$), at a pressure of 15,000 kPa (2175 psi) at 21°C. As this pressure is much too high to be delivered to the torch, a reducing valve or high pressure requlator is attached to the bottle. This reduces the pressure of the gas to that required at the torch. (Note that oxygen regulators are right-hand-threaded while acetylene regulators are left-hand-threaded). The space within the oxygen cylinder amounts to only a little more than 42 dm^3 (1.5 $ft.^3$), and it can be readily seen how much the oxygen must be compressed in order to confine 6,910 dm^3 (244 $ft.^3$) in so small a space. These cylinders should never be dropped, and should always be handled with care.

Oxygen is not inflammable, but is a supporter of combustion. When oxygen comes in contact with oil or grease, the latter becomes very inflammable. For this reason, no oil or grease should be used on regulators. The bottles should never be stored where there is any chance of oil dripping on them, or near hot stoves or pipes. Oxygen, like other gases, expands with heat and the pressure might increase to a point where the safety disc on the cylinder valve bursts, allowing the oxygen to escape.

Acetylene gas is the gas which burns in an oxy-acetylene flame. When it burns without being previously mixed with oxygen, it produces a yellowish, smoky flame. When mixed with oxygen, it produces a bluish white flame.

Acetylene is a heavy, invisible gas, which has a characteristic odor. It is entirely different from oxygen. It has peculiar characteristics which make it necessary for entirely different treatment when it is compressed into cylinders.

Acetylene gas is produced from calcium carbide and water in an acetylene generator. These generators have pop valves that are designed to release the pressure at 100 kPa (15 psi). If acetylene gas were compressed in an ordinary tank to over 100 kPa (15 psi), it would not be safe and could explode. Because of this, the acetylene cylinder is completely filled with a porous material made of charcoal, asbestos, corn pitch and other materials. This porous filler is completely saturated with acetone. Acetone is a by-product from the manufacture of wood alcohol and it has the peculiar property of dissolving acetylene gas. One volume of acetone will absorb 25 volumes of acetylene gas, for every 100 kPa (15 psi). If the pressure is reduced, the acetylene gas is released.

When acetylene gas is compressed into cylinders filled with porous material saturated with acetone, it is safe to handle and ship. The pressure within the acetylene cylinder is about 1,700 kPa (250 psi) at 21°C. In cold weather, this pressure drops due to the gas contracting. If the cylinder is placed in a warm room for several hours, the gas will again expand and show a tank pressure of 1700 kPa (250 psi). Do not place acetylene cylinders in front of a furnace or against hot pipes.

Cylinders are equipped with one or more fusible plugs. These are steel plugs, through which a hole has been drilled. The hole is filled with fusible metal which will melt at approximately 115°C. These plugs are screwed into the cylinder so that in case of fire, the fusible metal will melt and release the gas before the abnormal pressure would burst the bottle.

The amount of gas in an acetylene cylinder is determined by the weight of the gas. The weight of the empty cylinder is stamped on each cylinder, so by weighing a cylinder after charging and subtracting the empty weight, you will have the weight of the gas in the tank.

Acetylene gas is made up of 93% carbon and 7% hydrogen. As with oxygen, the pressure within an acetylene cylinder is too great to use at the torch, therefore, a reducing valve or high pressure regulator is needed. All acetylene regulators are fitted with left hand threads, this being a safety factor, so they cannot be put on right-hand-threaded oxygen cylinders.

When setting up the equipment, care should be taken to make certain that the cylinders are secured so they cannot be tipped over. After securing cylinders, remove protecting caps and open cylinder valves slightly and then shut them again. This is to blow out any dirt that might be in the valves. Regulators may then be put on. Connect hoses and torch. Open tank valve and turn pressure on the regulator to the torch (The oxygen tank valve is opened fully; the acetylene tank valve is opened 3/4 turns). Check all joints with soap suds and water for leaks; also check the valve stem on top of acetylene bottle. Once all joints are sealed, bleed hoses and prepare for torch lightup.

Preparation for Welding

Torch Lightup

Before lighting the torch, open the torch needle valves one at a time to purge the lines of any air or explosive mixture that may exist in the lines. This is an especially good rule to follow where more than one person may be using the equipment.

Having purged both lines, now open the acetylene needle valve about ½ turn and light the torch. Do not light torches using a mixture of oxygen and acetylene! This is a dangerous practice!

When acetylene is ignited, the flame is smoky, giving off an excess of stringly black carbon. This can be greatly reduced by opening the acetylene needle valve more fully. This will help to keep the air and shop clean.

In lighting the torch, watch that you do not direct the flame towards other persons, or against surfaces which should be kept clean, or into a confined space where it may ignite with violence.

Regulators are made to stand moderate abuse and designed to give a rough estimate of pressures. They are accurate enough for cutting, but in welding, maximum control of flame settings is a must and the balancing of pressures is mandatory to good flame control.

Flame Adjustment

(1) Having opened the acetylene needle valve ½ turn and ignited the acetylene, we now want to establish the maximum amount of acetylene that can be burned with satisfaction for the tip in use. This is done by opening the acetylene needle valve fully, or at least beyond the point where the flame ceases to increase in size.

(2) Now adjust the acetylene pressure at the regulator so that the flame blows away from the tip, but not violently so. For example: using a No. 3 tip, the flame will blow away about 10 mm (3/8") to 12 mm (½") without becoming too harsh in sound. Smaller tips would require less blow away.

Some operators use the following "rule of thumb": A small tip such as No. 3 would be set to blow away the thickness of the little finger, while No. 7 size tips should blow away about the width of the thumb 18 mm (3/4") to 25 mm (1"). We have now established maximum acetylene pressure and flow.

(3) If oxygen is introduced to the flame while the acetylene needle valve is at maximum, the flame will blow out. For this reason, we must bring the flame back to the tip before adding oxygen. This is done by partially closing the acetylene needle valve. It will now be noticed that the flame is smoky, and smoke on the acetylene flame indicates too little gas flow and would cause backfires if we proceeded to use this amount of flame in welding. Increase the acetylene flow by opening the needle valve until the smoke disappears. At the point where the smoke disappears, we have established the minimum gas flow for the tip.

(4) Now add oxygen to the flame by slowly opening the oxygen needle valve until a cone is formed. Alternating between valves, keep opening first acetylene and then oxygen valves until the maximum acetylene flow is reached.

(5) Finally, with the oxygen needle valve open to full flow, adjust the oxygen pressure at the regulator so that the neutral flame is formed while both needle valves are fully open. NOTE: Your original oxygen working pressure setting may have been too high. In this case, an oxidizing flame will be formed before you have the oxygen needle valve opened to

full flow. Therefore, you must reduce the oxygen pressure at the regulator until you can open the oxygen needle valve to full flow and have a feather showing on the flame. Then with both needle valves fully open, slowly increase oxygen pressure at the regulator until the feather just disappears (and no more) and you will have established neutral flame.

While both needle valves are fully open, you have established maximum flame for this tip. Any attempt to increase pressures and gas flow upward from this point will produce a "harsh flame" which tends to agitate the puddle, allowing air to come in contact with the molten metal and resulting in burned deposits.

(6) Finally, reduce the flame size to proportions suitable for the work in hand. This is done by partly closing both needle valves, thus reducing the flow of gases.

CAUTION: The flame must not be reduced to a point where the flame would be smoky if the oxygen flow was stopped by closing the needle valve. Working in what we call the "smoke range" (low gas speed) will result in backfires or popping.

Students are advised wherever possible to use the mid-capacity of the tip. In short, if you need enough heat that it is necessary to operate a tip at maximum, you would get far better results by using a larger size tip at mid-capacity.

NOTE: By setting the flame to neutral with both needle valves at full flow, you will be balancing to equal pressures, since an equal amount of oxygen and acetylene are required from the cylinders to form a neutral flame.

It is very important that the operator learns to distinguish flame types

Types of Flames

Neutral flame- temperature 3260°C - balanced mixture of oxygen and acetylene. The color of the flame is reddish-purple. The inner cone is clearly defined and is usually from 2 to 3 times as it is wide at the end of the tip.

When welding mild steel, the molten puddle is quiet and clear and is easily controlled. There is a minimum of sparking.

Carbonizing flame - temperature 3150°C - excess of acetylene. The color of the flame is a greenish hue around the inner cone ranging to reddish-orange through the outer envelope of the flame. The inner cone is indistinct, having a feather on it. When welding mild steel, the molten puddle turns dark and boils. This flame adds carbon to the metal leaving it brittle and weak.

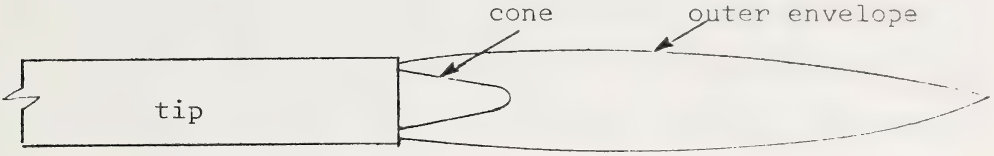
Oxidizing flame - temperature 3480°C - excess of oxygen. The color of the flame is violet ranging to deep purple. The inner cone is shorter, and the flame has a harsh sound.

When welding mild steel, the molten puddle turns white and foams around the edges. There is a maximum of sparking.

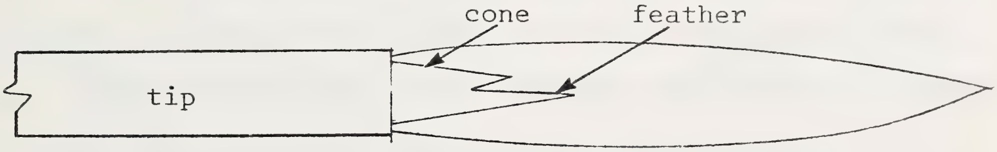
This flame oxidizes or burns the metal, leaving it porous and weak. For this reason, an oxidizing flame should never be used for steel welding.

Flame Diagrams

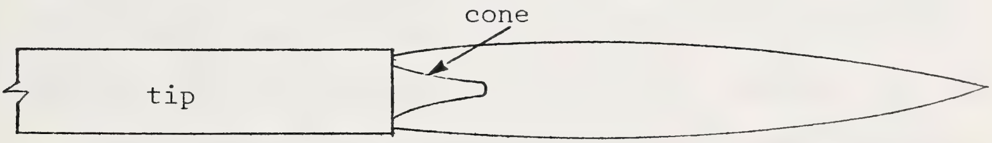
Neutral Flame



Carbonizing Flame



Oxidizing Flame



Safety Hints

Never light a torch until you are sure equipment isn't leaking.

Don't lay a lighted torch down.

Never use oil on oxygen valves, fittings or regulators.

Be sure torch is pointing away from persons or equipment.

Be careful with clothing.

Keep sparks or flame away from hoses and equipment.

Keep acetylene key on bottle. In case of fire, you will be able to shut the cylinder off quicker.

Wear your goggles. You only have one set of eyes.

Welding Techniques

Fusion Welding

Fusion welding is the process of joining 2 or more pieces of metal in which all bonding surfaces are heated to their melting points. In gas welding, the required heat is produced by burning a combustible gas (usually acetylene, propane or hydrogen) with oxygen. Sometimes heat from the gas flame is used to melt and fuse the metal parts together without adding extra metal, but most often molten metal is added to the joint from a gas welding rod of suitable material.

Fusion welding of steel can be carried out in all positions, but flat welding is preferred as it can be done reasonably well without a great deal of experience. Good welds in the vertical, horizontal and overhead positions require a greater degree of operator skill.

Brazing and Soldering

Both brazing and soldering are accomplished by bonding metal surfaces together using a nonferrous filler metal, which has a melting point below that of the bonded metals. Virtually all metals may be bonded by either brazing or soldering. Metals used for brazing include copper, silver and aluminum alloys. Solder is usually made from tin, lead and antimony. Some special solders also contain silver. The major difference between soldering and brazing is the melting point of the filler material: solders melt at temperatures less than 430°C, brazing rod melts at temperatures greater than 430°C.

When using coated bronze, care must be taken to keep the molten puddle at the right temperature. It must be hot enough to "wet" the surfaces being joined, but not so hot that zinc is vaporized. Brazing can be done in all positions. Care should be taken to avoid inhaling fumes. Both soldering and brazing should be done in a well-ventilated area.

Flame Cutting

On many farms where an electric-arc welder is available, oxy-acetylene is used primarily as a means of cutting metal. Flame cutting of ferrous metals is a chemical action in which oxygen combines with the iron to form iron oxide. In cast iron, this process is hindered by the presence of carbon in the graphite form. In steel, the cutting reaction begins at bright red heat.

The cutting torch tip has a circle of small heating jets and a larger central port through which pure oxygen may be introduced to initiate cutting. With this configuration, a heating flame will always precede the oxygen jet regardless of the direction the torch is moved.

The torch is lit and the heating flames adjusted to neutral. When the oxygen lever is depressed, the flame should remain neutral. If it does not remain neutral, then readjust the oxygen to the preheating tips until the flame remains neutral with the oxygen valve open.

When cutting steel plate, the preheat flame is put in contact with the edge of the plate and quickly raises it to a "bright red" temperature. Then the oxygen valve is opened by pressing the lever on the torch handle and as pure oxygen comes in contact with the heated plate, the metal is burned (or oxidized) away. For uniform manual cutting, the operator should be in a comfortable position with the torch hand supported so that he may complete the cut with one smooth motion.

TORCH SETTINGS

TABLE 1. Properties of Fuel Gases

Fuel Gas	BTU's Cu. Ft.	Flame Temp.*	Oxygen Per Cu. Ft. of Fuel*
Acetylene	1433	5420°F	1.04
1) MAPP	2381	5301°F	2.4
Propane	2309	5190°F	4.00
2) Natural Gas	918	5000°F	1.50
Hydrogen	275	4600°F	0.25

* All the figures above are based on Neutral Flame conditions. Slightly higher flame temperatures can be attained for most of these gases by burning them in an oxidizing flame. Oxidizing flames require higher oxygen consumption. If the often quoted 6300° temperature for acetylene were used, then figures for the other four gases would be respectively higher.

1) MAPP Gas date supplied by Dow Chemical Co.

2) Natural gas data varies with exact composition in different geographic areas.

TABLE 2. Tip Size and Cutting Pressure for Airco and Liquid AIR Acetylene Cutting Torches

Approximate Tip Sizes, Cutting Speeds and Gas Pressures for C.L.A. Cutting Torches and Light Preheat Tips (Style 801)

Thickness of Metal - In.	Tip No.	Oxygen Pressure psi	Oxygen Flow - cfh	Acetylene Pressure psi	Acetylene Flow - cfh	Hand Cutting Speed - In./Min.
¼	0	30	45	3	9	16 - 18
3/8	1	30	75	3	12	14.5 - 16.5
½	1	40	85	3	12	12 - 14.5
3/4	2	40	120	3	13.5	12 - 14.5
1	2	50	140	3	13.5	8.5 - 11.5
1½	3	50	180	3	16	7 - 7.5
2	4	50	225	3	16	5.5 - 7
3	5	60	290	4	20	5 - 6.5
4	5	60	330	4	20	4 - 5
5	6	50	360	5	27	3.5 - 4.5
6	6	55	390	5	27	3 - 4
8	7	60	540	6	36	2.5 - 3.5
10	7	70	625	6	36	2 - 3
12	8	70	760	6	36	1.5 - 2

Pressures and consumptions shown are approximately correct for tips with light preheating flames when used on clean plate. On rusty or painted surfaces, use Style 802 tips with medium preheat flames. These tips require the same oxygen pressure as shown for the Style 801 tip, but slightly higher acetylene pressures. Gas pressures should be increased slightly for hose lengths greater than 25 feet.

TABLE 3. Tip Size and Cutting Pressure for Victor Acetylene Cutting Torch

CUTTING TIP CHART
Cutting Tip Series: 1-101, 3-101, 5-101, 1-104

Metal Thickness	Tip Size	Speed I.P.M. Max./Min.	Oxygen Cutting PSIG Min./Max.	Oxygen Pre-Heat PSIG Min./Max.	Acetylene PSIG* Min./Max.	KERF Width
1/8"	000	28/32	20/25	For 3--Hose Machine Torches Only See Below	3/5	.04
¼"	00	27/30	20/25		3/5	.05
3/8"	0	24/28	25/30		3/5	.06
½"	0	20/24	30/35		3/5	.06
3/4"	1	17/21	30/35		3/5	.07
1"	2	15/19	35/40		3/6	.09
1½"	2	13/17	40/45		3/7	.09
2"	3	12/15	40/45		4/9	.11
2½"	3	10/13	45/50		4/10	.11
3"	4	9/12	40/50		5/10	.12
4"	5	8/11	45/55		5/12	.15
5"	5	7/9	50/55		5/13	.15
6"	6	6/8	45/55		7/13	.18
8"	6	5/6	55/65		7/14	.19
10"	7	4/5	55/65		10/15	.34
12"	8	3/5	60/70		10/15	.41

*NOTE: Data above applies with the following exceptions:

Torch Series	Pre-Heat Oxygen	Pre-Heat Fuel
MT600 A Series	40 PSIG-UP	2 PSIG-UP
MT500 Series	30 PSIG-UP	5 PSIG-UP

*Oxygen consumption is 1.1 times the acetylene under neutral flame conditions. Gas consumption data is merely for rough estimating purposes. It will vary greatly on the material being welded and the particular skill of the operator.

All pressures are measured at the regulator using 25' x ¼" hose through tip size 5, and 25 x 3/8" hose for tip size 6 and larger. Use 3/8" hose when using tip size 6 or larger.

TABLE 4. Harris Series 2490-VVC Machine Cutting Tips

For Propane & Natural Gas (4 oz. pressure or more) for all models of Harris 98-2F Torches
as will as Certain Models of Oxweld, Airco, Victor, NCG, Purox and Smith (see chart)
Use Harris High Speed 2940-VVCM Tips with Oxy-MAPP Gas

Plate Thickness (Inches)	Tip Size	Cutting Speed in./min.	*Cutting Oxygen Pressure	Fuel Gas Pressure	Width Kerf (Inches)	Plate Thickness (Inches)	Tip Size	Cutting Speed in./min.	*Cutting Oxygen Pressure	Fuel Gas Pressure	Width Kerf (Inches)
1/16	2490-5/0VVC	20-24	40	4 oz. or more	.035	2½	2490-1VVC	7-12	90	4 oz. or more	.08
1/16	2490-000N	20-24	40	2 PSI	.064	3	2490-1½WC	7-10	95	4 oz. or more	.09
1/8-1/16	2490-5/0VVC	22	60	4 oz. or more	.035	4	2490-2VVC	7-9	95	4 oz. or more	.09
1/8-3/16	2490-000N	22	60	2 PSI	.064	5	2490-2VVC	7-8	105	4 oz. or more	.09
1/4	2490-4/0VVC	20	40	4 oz. or more	.06	6	2490-2½VVC	7	95	4 oz. or more	.09
1/4	2490-000N	22	50	2 PSI	.064	7	2490-3VVC	6-7	100	4 0z. or more	.11
3/8	2490-000VVC	18-22	75	4 oz. or more	.065	8	2490-4VVC	6-7	95	4 oz. or more	.13
1/2	2490-00VVC	18-20	75	4 oz. or more	.075	9	2490-5VVC	5-6	90	4 oz. or more	.15
3/4	2490-0VVC	15-18	90	4 oz. or more	.075	10	2490-5½VVC	4-5	90	4 oz. or more	.17
1	2490-0½VVC	14-17	100	4 oz. or more	.075	11	2490-5NH	4-5	60	4 oz. or more	.23
1¼	2490-0½VVC	14-16	100	4 oz. or more	.075	11	2490-6NH	4-5	60	4 oz. or more	.26
1½	2490-1VVC	13-15	100	4 oz. or more	.08	12	2490-7NH	4-4½	60	4 oz. or more	.27
2	2490-1VVC	13	105	4 oz. or more	.08	15	2490-8NH	4	60	4 oz. or more	.29

* It is important correct cutting oxygen pressure be availabe at the torch.

For light plate cutting, carburizing pre-heat flames are recommended. For heavy plate cutting, strong pre-heat flames are recommeded for entering cut.

TABLE 5. Harris Series 2490-NFF and 2490-NX THRIF-T-TIPS

2490-NS and 2490-NFF cutting tips fit Harris Oxy-propane and Oxy-natural Bas Apparatus as will as certain models of Oxweld, Airco, Victor, NCG, Purox and Smith. (see Chart)

2490-NX

Normal preheat for clean surface straight line and shape cutting

Plate Thickness Inches	Tip	Oxygen Pressure	Natural Gas or Propane Pressure	Cutting Oriface Drill Size
Light Guage to 3/16	2490-000NX	15-30	4 oz. or more	#68
3/16-3/8	2490-00NX	20-30	4 oz. or more	#64
3/8-5/8	2490-0NX	30-40	4 oz. or more	#60
5/8-1	2490-1NX	35-50	4 oz. or more	#56
1-2	2490-2NX	40-55	4 oz. or more	#52
2-3	2490-3NX	45-60	4 oz. or more	#48
3-6	2490-4NX	50-75	4 oz. or more	#42
6-8	2490-5NX	65-80	4 oz. or more	#35
8-12	2490-6NX	70-90	4 oz. or more	#30

2490-NFF

Heavy preheat for rust or scale covered surface hand cutting

Plate Thickness Inches	Tip	Oxygen Pressure	Natural Gas or Propane Pressure	Cutting Oriface Drill Size
to 5/8	2490-1NFF	20-35	4 oz. or more	#56
5/8-2	2490-2NFF	20-55	4 oz. or more	#53
2-4	2490-3NFF	45-65	4 oz. or more	#47
4-7	2490-4NFF	55-75	4 oz. or more	#42
7-10	2490-5NFF	60-80	4 oz. or more	#35
10-12	2490-6NFF	80-90	4 oz. or more	#31

Use 2490-NXM Tips with Oxy-Mapp Gas

Harris E-9 Looped Wire Tip Cleaners wre the recommended tool for cleaning tips.

TABLE 6. Tip Size and Welding Pressures for Harris Acetylene Welding Torch

Thickness of Metal In Inches	Size Of Tips	Size of Welding Rod	Oxygen Pressure, P.S.I.	Acetylene Pressure, P.S.I.
3/64"	1	1/16"	1	1
1/16"	3	1/16"	3	3
3/32"	5	3/32"	5	5
1/8"	5	1/8"	5	5
3/16"	7	5/32"	7	7
1/4-3/8"	9	3/16-1/4"	9	9

TABLE 7. Tip Size and Cutting Pressures for Harris Acetylene Cutting Torch

Thickness of Metal in Inches	Size* of Tip	Oxygen* Pressure, P.S.I.	Acetylene* Pressure, P.S.I.
1/8" - ¼"	00	25-35	6
3/8"	0	25-35	6
½" - 1"	1	35-45	6
2"	2	45-50	6
3" - 4"	3	45-55	6
5" - 6"	4	55-65	6

* Tip Size and pressure may vary according to operator choice. This chart should serve as a guide or reference.

TABLE 8. Tip Size and Welding Pressures for Airco and Liquid Air Welding Torches.

APPROXIMATE TIP SIZES AND GAS PRESSURES FOR C.L.A. WELDING TORCHES AND TIPS

Tip No.	Thickness of Metal - In.	Oxygen & Acetylene Pressure - psi	Acetylene Flow - cfh	Oxygen Flow - cfh
00	1/64	1	0.1	0.1
0	1/32	1	0.4	0.4
1	1/16	1	1	1.1
2	3/32	2	2	2.2
3	1/8	3	8	8.8
4	3/16	4	17	18
5	1/4	5	25	27
6	5/16	6	34	37
7	3/8	7	43	47
8	1/2	8	52	57
9	5/8	9	59	64
10	3/4 +	10	67	73

Pressures and consumptions shown are approximately correct for both separable tips with appropriate mixers and for tip-mixer assemblies.
Gas pressures should be increased slightly for hose lengths greater than 25 feet.

TABLE 9. Tip Size and Welding Pressures for Victor Welding Torches

ACETYLENE
Welding Nozzles - All Types

Metal Thickness	Tip Size	Drill Size	Oxygen Pressure	Acetylene Pressure P.S.I.G.
			Min./Max.	Min./Max.
up to 1/32"	000	75	3/5	3/5
1/64"-3/64"	00	70	3/5	3/5
1/32"-5/64"	0	65	3/5	3/5
3/64"-3/32"	1	60	3/5	3/5
1/16"-1/8"	2	56	2/5	2/5
1/8"-3/16"	3	53	4/7	3/6
3/16"-1/4"	4	49	5/10	4/7
1/4"-1/2"	5	43	6/12	5/8
1/2"-3/4"	6	36	7/14	6/9
3/4"-1 1/4"	7	30	8/16	7/10
1 1/4"-2"	8	29	10/19	8/12
2"-2 1/2"	9	28	12/22	9/14
2 1/2"-3"	10	27	14/24	10/14
3"-3 1/2"	11	26	16/26	11/15
3 1/2"-4"	12	25	18/28	12/15

TABLE 10

MULTI-FLAME NOZZLES - TYPE 11, 28 AND 29

Tip Size	Acetylene Pressure Range P.S.I.G. Min./Max.	Oxygen Pressure Range P.S.I.G. Min./Max.	Acetylene Consumption (SCFH) Min./Max.	Oxygen Consumption (SCFH) Min./Max.
2	3/5	5/8	3/9	3/10
4	4/7	6/10	4/19	4/21
5	4/7	6/10	6/20	7/22
6	8/12	8/12	14/40	15/44
7	4/8	8/12	20/60	22/66
8	8/12	10/20	30/80	33/88
10*	10/12	15/20	40/100	44/110
12*	12/15	20/60	60/150	66/165
15*	12/15	20/60	90/220	99/244

*NOTE: Use HD310 and 3/8" hose for tip sizes 10, 12 and 15.

CAUTION: At no time should the withdrawal rate of an acetylene cylinder exceed 1/7 of the cylinder contents per hour. If additional flow capacity is required use an acetylene manifold system of sufficient size to supply the necessary volume.

AC ELECTRIC-ARC WELDING THEORY

Description of Equipment

In electric-arc welding,the heat required results from an arc produced by an electric power source. Both alternating current (a.c.) and direct current (d.c.) electric power can be used, but a.c. is more commonly used on the farm. Many types and makes of a.c. electric-arc welding machines are available. Three general types are:

1. Adjustable resistor type - seldom used.
2. Transformer with fixed voltage terminals (current can only be adjusted in steps).
3. Transformer with movable core. (Current can be adjusted continuously).

High current capacity electric cable is used to connect the welding terminals to the workpiece. The ground cable is clamped to the work (or conducting work table), and the other cable connects the welding terminal to the electrode holder. Touching the electrode fixed in the holder to the workpiece completes the circuit and produces a high temperature arc at the electrode tip.

Electrode Selection

The following information has been compiled in an effort to give you a clearer outline of the electrode standards. The electrode manufacturers make electrodes to meet certain standards and the electrodes must meet these standards, otherwise they are rejected.

Most electrode boxes are labelled A.W.S., A.S.T.M., or C.S.A., A.W.S. is the American Welding Society. A.S.T.M. is the American Society for Testing Materials. C.S.A. is the Canadian Standards Association.

The numbers following the above letters are the electrode classifications. This classification tells us all we need to know for practical welding purposes. What do these numbers mean?

E6010 - "E" indicates that the rod in question is used for electric welding. The first 2 digits (60) indicate the minimum tensile strength in thousand pounds per square inch (P.S.I.)

The third digit (1) indicates that this rod will operate in all positions - flat, vertical and overhead. Where the third digit is number 2, such as E6020, the rod will operate only in two positions, flat horizontal and flat. Where the third digit is number 3, such as E6030, the rod will operate in only the flat position.

The last 2 digits read together tell us whether straight or reverse polarity current can be used.

E6010	Reverse polarity electrode positive
E6011	A.C. and reverse D.C.
E6012	D.C. straight and A.C.
E6013	D.C. straight and reverse and A.C.
E7014	D.C. and A.C.
E7018	D.C. and A.C.

It is not generally known that the wire in all of the above mentioned electrodes is the same. It is the coating that brings about the different handling and deposited weld metal qualities.

It should also be noted here that as the tensile strength goes up, the elongation "stretch" goes down. It is, therefore, not reasonable to expect an E80XX or 90XX electrode to have the elongation of an E60XX electrode.

E6010 electrodes have a high cellulose content in the coating which produces large volumes of carbon dioxide and water vapor. This protects the deposited metal from the atmosphere even though the slag deposit is very low. In most cases, the slag can be removed easily with a wire brush. The slag deposit, being small, cools quickly making it easy to handle in vertical and overhead positions. The quality of the deposited metal is good and is used on pipe work, tanks and, in fact, all welding where the following are required: all position welding, good stretching qualities, good tensile strength and good penetration.

This rod is listed as E6010, but the deposited weld metal, unless stress relieved or annealed, will be much higher in tensile strength. It will probably be from 450,000 kPa (65,000 psi) to 520,000 kPa (75,000 psi) or even higher if the weld has been quickly cooled.

The elongation will likely be from 22 to 28% in 50 mm (2"). If stress relieved, the results will be 410,000 kPa (60,000 psi) to 500,000 kPa (72,000 psi), and the elongation will increase to about 29 to 37% in 50 mm (2").

It will easily be seen that stress relieving a weld will certainly prevent a lot of cracking. The tensile strength will still be above the classification range of 410,000 kPa (60,000 psi).

The same thing applies to all welding except that the tensile strength and elongation vary with each different classification of rods.

E6011 Electrodes - these rods are made to be used with an A.C. machine and to give results equalling the E6010 rod (E6010 will not work with an A.C. machine). This rod will work with a D.C. machine also and can be used generally on any work where an E6010 is specified.

E6012 Electrodes - this rod is a general purpose electrode. It is a straight polarity rod used with D.C. current, electrode negative. It can be used with an A.C. machine, but at low heats it has a tendency to burn off in lumps. These rods donot have the stretching qualities of E6010. The coating is usually grey or grey black in color, but color varies according to the manufacturer. The heavy slag on this rod covers the weld to protect it from the atmosphere. If properly applied, the slag is easily removed, leaving the weld metal bright and clean. Penetration is somewhat lower than E6010. The ease of handling is a definite factor, but unfortunately, unless care is taken, slag can be trapped in the welds and often the root of the weld is not welded. On large weldments and in cold weather, cracking may occur in the first and second beads unless preheated. This rod is used extensively for building up mild steel shafts, fabrication of structural steel and general welding. The composition of the core wire is the same as E6010, but "as welded" the results are different.

The "as welded" tensile strength is approximately 480,000 kPa (70,000 psi) to 570,000 kPa (82,000 psi). The "as welded" elongation in 50 mm (2") approximates 18 to 23%. By stress relieving this weld, the results would likely read: tensile strength 450,000 kPa (65,000 psi) to 550,000 kPa (80,000 psi); elongation is 50 mm (2") 24 to 27%.

E6013 Electrodes - this rod is becoming very popular because of its flexibility of operation. It will work D.C. straight and reverse and will also work well with an A.C. machine. The deposited metal is smooth and the slag removal is excellent. In fact, with proper application, the slag will raise from the weld when cool without assistance. It can be used in all positions, but once again, it is not as easy to handle as E6011 in overhead and vertical positions. The penetration is about the same as E6012 and its uses are about the same. The cost is slightly higher than E6012 because of the coating composition. The breakdown of this rod as welded would be about the same as E6012.

E7014 Electrodes- these are a general purpose rod, used with the D.C. machine (either polarity) or A.C. Coating is generally black in color and contains iron powder, giving a higher deposit rate. The heavy slag protects the weld deposit and removal is easy.

E7018 Electrodes - have low hydrogen coating which produces a crack-resistant weld. Have a smooth steady arc action. Slag is easy to remove after cooling. Designed for high quality, high speed welding on an unsually wide range of carbon and alloy steels.

Special Electrodes- careful selection of nickel, aluminum and hard surfacing rods is essential. Consult your supplier.

Preparation for Welding

Setting the Current (Heat)

The correct current setting on the electric welding machine is determined mainly by the properties of the material to be welded, the welding position and the electrode diameter. The following chart gives an indication of approximate currents for welding mild steel.

Figure I

CURRENT REQUIREMENTS FOR MILD STEEL ELECTRODES

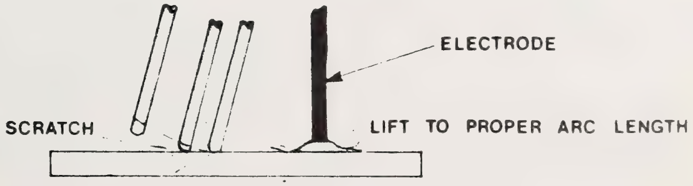
Electrode	Amperage	
Diameter	Min.	Max.
5/64	20	50
3/32	40	80
1/8	65	125
5/32	90	160
3/16	120	180

Striking an Arc

Before striking an arc, fit the electrode into the holder, position the electrode near the area to be welded and lower the helmet visor. Two common methods of striking an arc are illustrated in Figures II and III.

Scratching Method - in this method, the end of the electrode is dragged across the work in a manner much the same as striking a match. When the electrode contacts the work the current flows and an arc results. The electrode must then be moved away from the work and welding begun with the established arc. If the electrode is not moved away from the work on contact, then it may "stick" and have to be broken loose by a quick twist of the wrist.

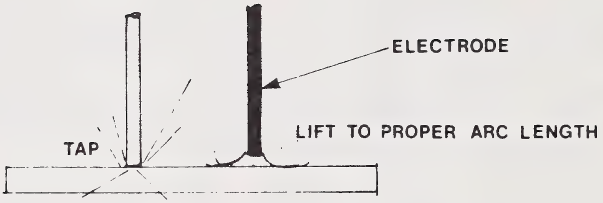
Figure II



Scratching Method

Tapping Method - in the tapping method, the electrode is brought straight down on the work and immediately after contact, is withdrawn to the proper arc length.

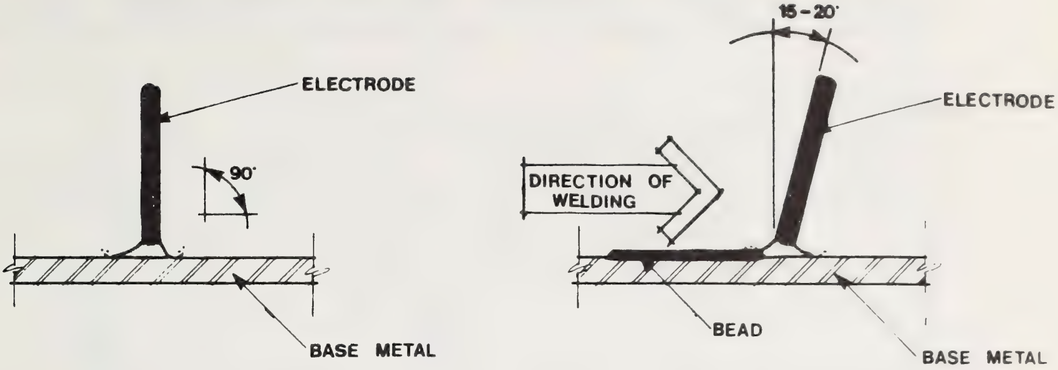
FIGURE III



Tapping Method

Generally, the scratching method is preferred for A.C. welding. The correct arc length is determined mainly by the electrode diameter. As a guide, use an arc length about equal to the electrode diameter. (Generally, beginners tend to use too long an arc). Once some skill is attained in striking and holding an arc, the next step is to practice running beads on flat plate. Once the arc is established, the electrode should be held perpendicular to the work or tilted slightly in the direction of travel. Practice running beads both right to left and left to right.

FIGURE IV



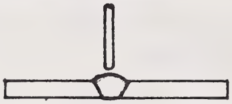
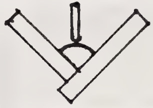
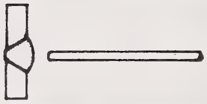
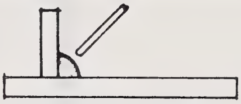
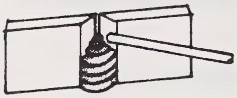
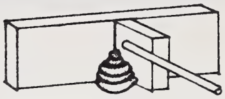
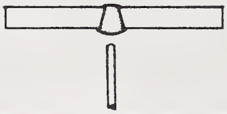
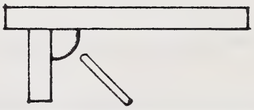
Welding Techniques

Position of Welds

With metallic arc welding, it is possible to deposit metal in any position so that an operator may make a joint that is below him, in front of him, above him or at any intermediate position between these three.

A weld is said to be made in the flat position, horizontal position, vertical position or overhead position depending on the position of the joint in relation to the floor. Welding techniques for the 4 positions of welding vary according to the ease of depositing metal. It is possible to deposit weld layers of considerable volume in the flat and vertical positions, but stringer beads are normally used for horizontal and overhead welding. These positions are better illustrated than described and are shown below for groove welds and fillet welds on a Tee joint.

FIGURE V

POSITION OF WELD	GROOVE	TEE - JOINT FILLET
FLAT		
HORIZONTAL		
VERTICAL		
OVERHEAD		

Laying Beads

A proper bead is shown below. To produce these results it is necessary to hold a short arc, travel at uniform speed and feed the electrode towards the arc at a constant rate.

FIGURE VI

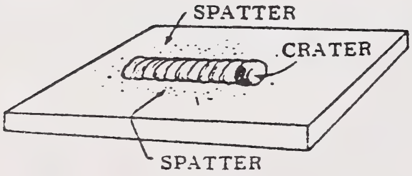
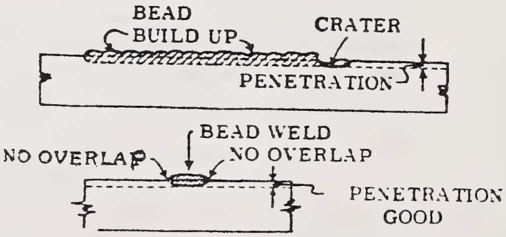


FIGURE VII



First attempts will probably fall short of the above and result in a bead which looks more like the one below.

FIGURE VIII

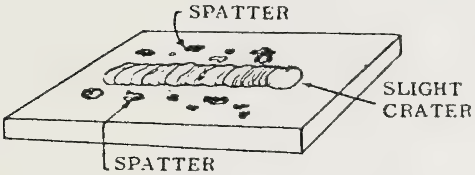
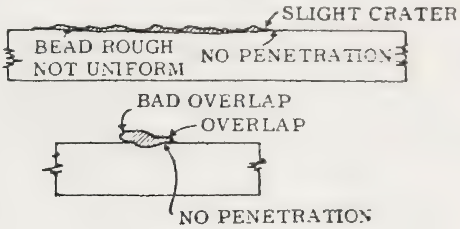


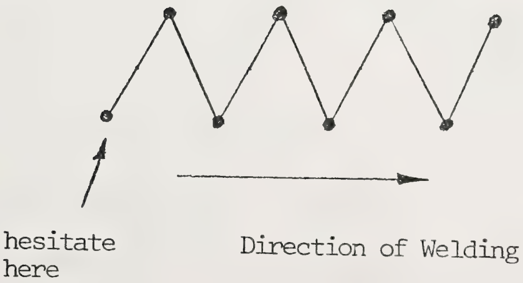
FIGURE IX



Practice laying beads by running them across the plate from left to right and right to left until the plate is covered with parallel beads. Clean each bead as you go and note the defects. Continue until there are no further defects.

When it is necessary to cover a wider area in one pass of the electrode, a method known as weaving is used. In order to produce a uniform deposit, a definite pattern of moving the electrode from side to side must be used.

FIGURE X



Weaving Pattern

While weaving is particularly useful in building up metal, it should be limited to weaves less than 6 times the electrode diameter.

It is always best to weld in the flat position, but this is not always possible. Welding on farm machinery must often be done in vertical or overhead positions as well. Once some skill is attained in laying consistent flat beads, rotate the flat plate to 45° with the horizontal and practice straight beads right to left, left to right and up the slope as illustrated below.

FIGURE XI

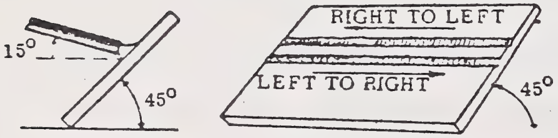
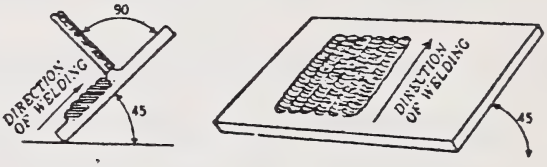
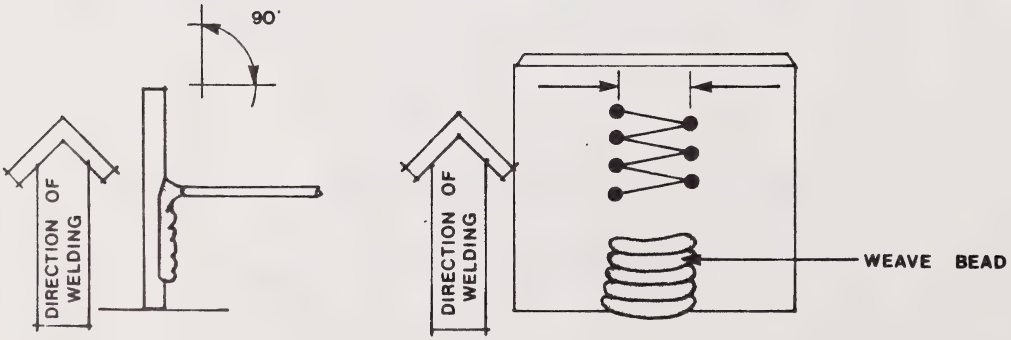


FIGURE XII



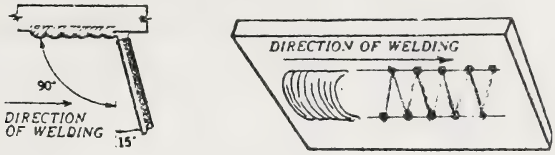
Once some proficiency has been attained, rotate the work to a vertical position and repeat the exercise. In each position weaving should also be practiced.

FIGURE XIII



The final and probably most difficult position is the overhead position. Again, both straight beads and weaving should be practiced.

FIGURE XIV



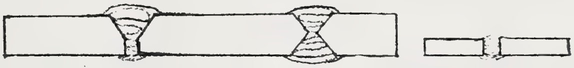
By this time you should be proficient in laying beads in all positions.

Weld Types

There are two basic weld types: the butt weld and the fillet weld.

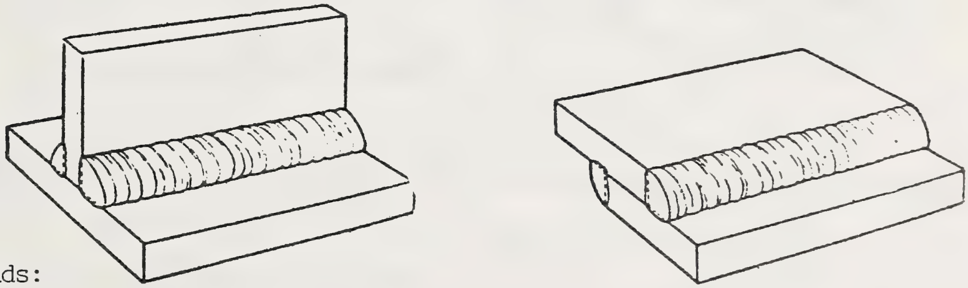
FIGURE XV

Butt Welds:



Single "V" **Double "V"** **Square**

Fillet Welds:



Tee Joint Lap Joint

Note that the weld should be cleaned thoroughly after each pass.

use right weld location for long repair life

Welding is an excellent way to repair breaks in farm machinery but unless careful thought is given to joint design and location of the welds, you could be wasting your time.

There are many things which you must consider in locating the weld. Here are a few:

- The location of the weld in its relationship to the metal being joined has a great effect on the strength of the joint. Normally welds made across the lines of stress are much stronger than welds which are parallel to stress lines (Fig. 1A).
- A member that is subjected to a moment (turning load) at a joint has a greater resistance to turning motions if the welds are spaced apart instead of being clost together (Fig. 1B).
- When joining shaped sections such as channels and angles, consideration must be given to proper distribution of loads on the welds. Notice in Fig. 1C that the length of the weld at the heel of the angle is greater than at the toe. This eliminates the tendency for the angle to turn and generate highly eccentric loads at the joint.
- To get uniform distribution of loads in linear welds, it is better to weld all around the joint than simply on two sides (Fig. 1D). (The welded piece shown can also be cut at an angle before welding for better strength.)
- Avoid abrupt surface changes in a weld joint since greater local stresses will be concentrated at the point of surface change. There is a more uniform transfer of stress through a weld if the surface flow is gradual (Fig. 2).

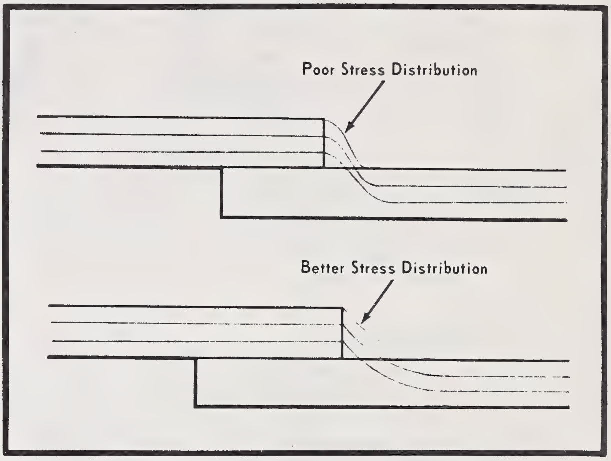
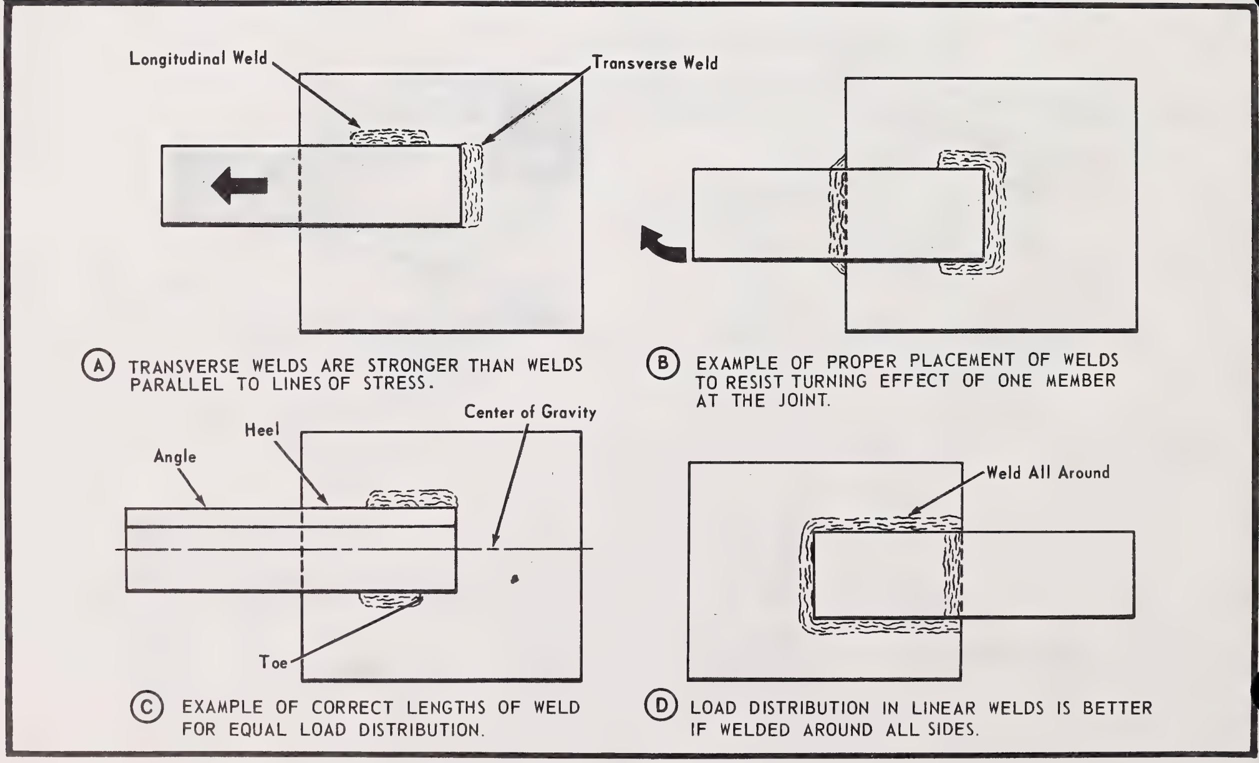


Fig. 2– Avoid abrupt surface changes in a joint



Ⓐ TRANSVERSE WELDS ARE STRONGER THAN WELDS PARALLEL TO LINES OF STRESS.

Ⓑ EXAMPLE OF PROPER PLACEMENT OF WELDS TO RESIST TURNING EFFECT OF ONE MEMBER AT THE JOINT.

Ⓒ EXAMPLE OF CORRECT LENGTHS OF WELD FOR EQUAL LOAD DISTRIBUTION.

Ⓓ LOAD DISTRIBUTION IN LINEAR WELDS IS BETTER IF WELDED AROUND ALL SIDES.

Fig. 1– Proper location of welds

- Locate weld joints so they are easy to read and welding can be done with comparative ease. Notice in Fig. 3 that the weld at (A) is almost impossible to make, whereas the weld at (B) is easily accessible.
- When an angle is used as a stiffener joined to a plate, use method (A) in Fig. 4 rather than (B). The weld location at (B) becomes more expensive since you will have to both bevel and machine the weld.

The recommended proportions for various joints to produce complete penetration of the weld material is shown in Figure 5.

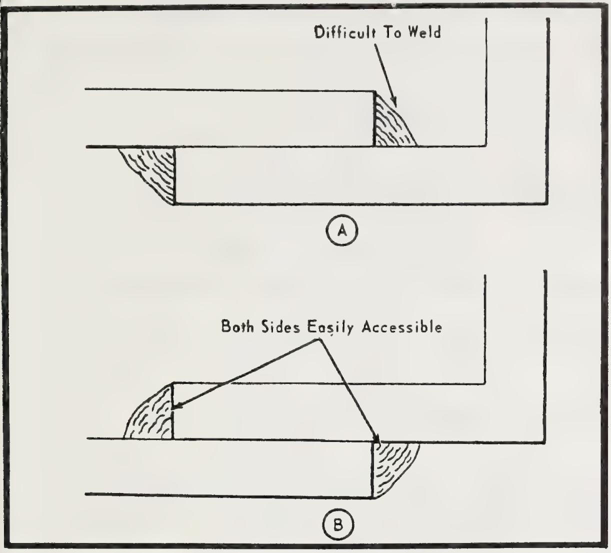


Fig. 3–Be sure that weld joints are easy to reach

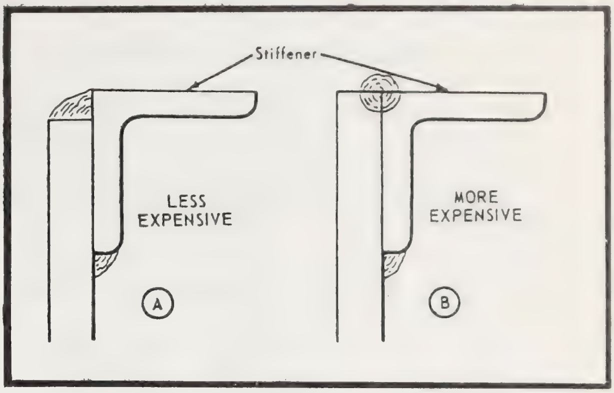


Fig. 4–Location of stiffener for economy welding

Source: John Deere Fundamentals of Service "Welding". It is available from UGG Farmer's Library for $6.45.

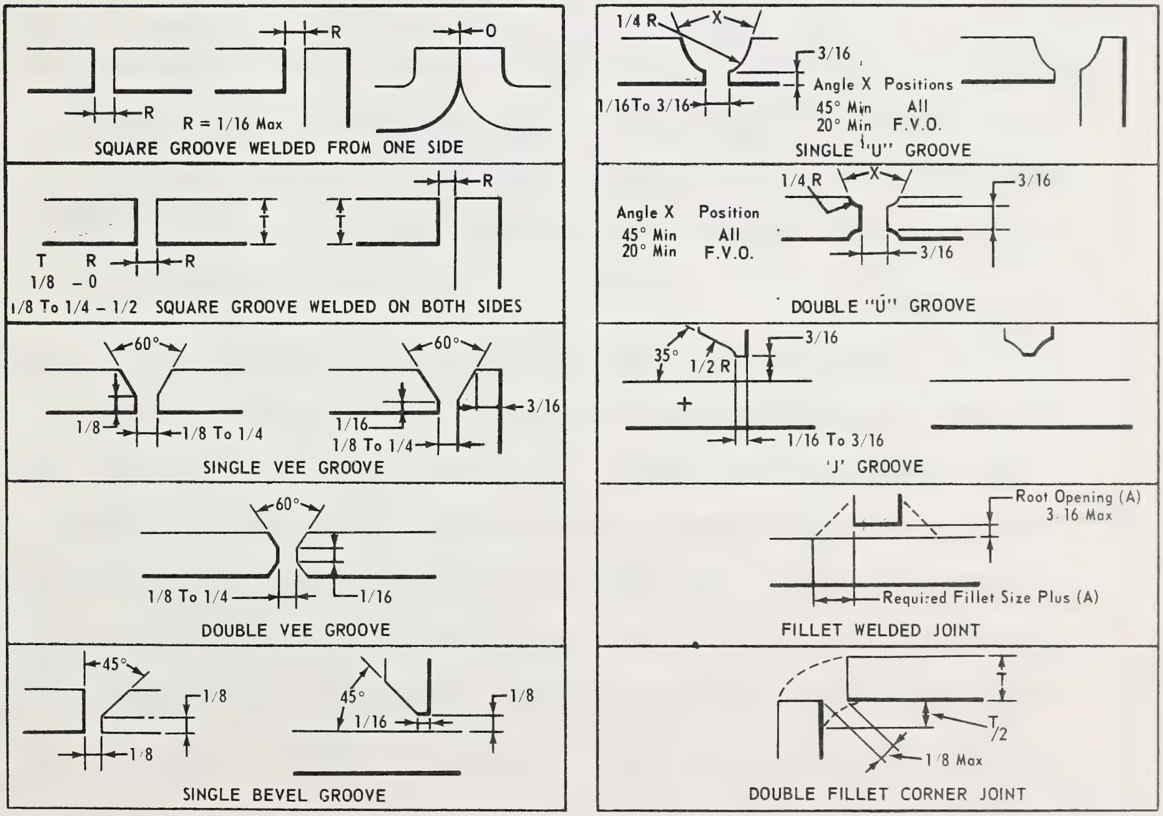


Fig. 5–Recommended proportions for various joints

Hard Facing

Hard facing metal parts subject to severe abrasion such as cultivator sweeps and plow shares can be accomplished most quickly and economically using the electric arc. By following these steps a uniform hard surface is assured:

(1) Choose the type of hard facing rod to be used carefully.

(2) Carefully clean metal parts to be hard surfaced.

(3) Set the welding machine for just enough current to maintain an arc.

(4) If possible, place the work in flat position.

(5) Use a medium long arc and move with a straight, weaving or circular motion (depending on width desired).

(6) If several layers are to be deposited, remove all slag between passes.

(7) If welds are overlapped, be sure to achieve good penetration at the overlap to bond adjoining welds.

(8) When surfacing an area along a thin edge, hold the arc over the heavy portion and then whip it out to the thin portion. This will result in a thin layer being deposited on the edge without dilution by the base metal.

Arc Cutting

Electric arc rods such as E6011 may be used for cutting steel. The heat of the arc is sufficient to melt the metal away leaving a very rough, ragged edge. Similarly, holes may be pierced by holding the arc over one spot until the plate begins to sweat. Then the arc is brought down into the molten pool and is pushed slowly through the metal. This method of cutting is best with thin plates in the flat position.

BASIC METALLURGY

Most metals may be satisfactorily welded, if a thorough knowledge of their structure, composition and characteristics are known.

Elements of Steel

In addition to iron, carbon steel contains 5 chemical elements. They are:

(1) Carbon
(2) Manganese
(3) Silicon
(4) Sulphur
(5) Phosphorous

The first 3, carbon, manganese and silicon are useful and of value owing to some distinctive property they give to the metal, or the power they possess of scavenging and purifying the metal by reacting upon the impurities and rendering them less harmful. The last 2, sulphur and phosphorous content, are kept as low as possible, although they cannot be completely eliminated.

Carbon: this is an element that partially gives steel that property whereby it may be hardened, drawn or annealed during its thermal treatment. By varying the amount and condition of carbon, ductility and workability are affected.

Manganese: next to carbon, this is the most important element in plain carbon steel. It has 2 main functions, both of which are of benefit to the steel. They form manganese dioxides, by eliminating the harmful impurity, ferrous oxide and combine with sulphur, forming manganese sulphide which tends to increase the hardness slightly and the toughness considerably. The average carbon steel contains from 0.03 to 0.08% of manganese.

Silicon: is used in steel as a scavenger. It acts as a gas eliminator, making the metal sound and free from blow holes and other gas cavities. Steel usually contains about 0.08 to 0.25% silicon.

Sulphur: if this element is present in excess of 0.10% or more in the steel, some of it will be in the form of iron sulphide which melts far below the melting point of steel and will thus break up the continuity and cohesion of the crystal masses in the metal causing brittleness. If only a small amount of iron sulphide is present, it will dissolve in the manganese sulphide.

Phosphorous: this is present as iron phosphide in solution and it is only when excessive amounts (about 0.10%) are present that segregation is likely to occur. When steel is cold, phosphorous is thought to be the cause of brittleness. During the production of steel, every effort is made to keep this element out.

Iron and Steel

The term "iron and steel" embraces a series of industrial alloys of iron and carbon, ranging from 99.9% to 94.0% iron and from 0% to 2% carbon, with traces of other elements and sometimes other alloying metals such as manganese, nickel, tungsten, etc. Iron is a chemical element taken from the earth in the form of iron ore. It is smelted in blast furnaces in contact with fuel and flux and from this process pig-iron is produced. Pig-iron is an impure product weak in tensile strength and non-malleable. For industrial purposes, it is refined and purified to improve ductility and other essential properties. This metal is known as steel. Wrought iron is the product of puddling furnaces.

In the production of iron and steel, the ultimate carbon content depends upon the process of manufacture. They may be defined as follows:

(a) Steel: is an iron carbon alloy, containing less than 2% carbon. It is cast from the molten state and forgeable at some temperatures, depending upon its composition.

(b) Cast Iron: contains more than 2½% carbon and is cast from the molten state and is not forgeable at any temperature.

(c) Malleable Iron: contains 2 to 2 3/4% carbon. Cast from a molten state as white iron, it is made malleable by heat treatment.

(d) Wrought Iron: contains less than 0.20% carbon and is not cast from the molten state. It is forgeable at some temperatures and usually contains about 1% slag.

(e) Alloy Steel: steel to which has been added 1 or more alloying metals for the purpose of conferring distinct and characteristic properties to the steel.

Plain Carbon Steels

The 3 grades of plain carbon steel are:

(1) Low Carbon Steel - 0.11% to 0.25% carbon

(2) Medium Carbon Steel - 0.30% to 0.50% carbon

(3) High Carbon Steel - 0.50% to 0.95% carbon

The number immediately following each class of metal designated in the following is its identification as to composition, as hereinafter explained.

Low Carbon Steel - (1010 - 1025) - used in bar, sheet and tubular form. The bar form is used in the annealed or cold rolled condition and has a minimum tensile strength of 380,000 kPa (55,000 psi).

Medium Carbon Steel - (1030 - 1045) - this is obtained in bar form and is used for parts requiring surface hardness and strength. It has a tensile strength of 550,000 kPa (80,000 psi) in the heat treated condition.

High Carbon Steel - (1050 - 1095) - this metal is used for parts that are subject to high shear and wear and where case hardening is not desirable. In the bar form in the annealed condition, it is used for the fabrication of tools, drills, taps, dies, etc., which are then heat treated. In the sheet form, it is used for both flat and coil springs and these are heat treated after forming.

Aluminum

This is a white, lustrous metal, recognized and noted for its lightness and non-corrosive properties. Aluminum that is 99% pure has a minimum tensile strength ranging from 86,000 kPa (12,500 psi) to 150,000 kPa (22,000 psi). It is supplied in bar, sheet extruded and tubular forms. It is used extensively in aeroplane construction for such parts as cowlings and fittings that do not have to bear stress. There are various alloys of this metal ranging in minimum strength up to 390,000 kPa (57,000 psi), the strongest of which is known as duralumin.

Melting Points of Metals

Name of Metal	Melting Point	Name of Metal	Melting Point
Wrought Iron	1510°C	Copper	1080°C
Pure Iron	1530°C	Aluminum	660°C
Cast Iron	1090°C-1260°C	Low Carbon Steel	1490°C-1520°C
Mild Steel	1370°C	Medium Carbon Steel	1400°C
Bronze	1000°C	High Carbon Steel	1330°C
Brass	880°C-1000°C		

Definitions:

Malleability: is the property which enables a metal to be beaten, hammered or rolled out into sheets, without fracture or detriment. When these metals are being formed or fabricated in a heated state, the term "forgeability" may be used.

Ductility: is that property which permits a metal to be rolled or drawn out by tension into a smaller section. Iron, steel and copper are noted for their ductility. Tenacity is closely related to ductility; a weak metal will break before it can be reduced in size. Zinc, tin and lead will not permit drawing out, because their tenacity is low. Ductile metals become hardened and crystallized during the drawout process.

Brittleness: denotes lack of ductility or malleability in a metal. It is the ease with which a metal will break after its elastic limit is exceeded. A brittle steel will have an elastic limit equal to its ultimate tensile or compression strength, therefore, its ductility will be 0.

Elasticity: is that property of a metal by virtue of which if it is distorted within certain limits, it will resume its original form when the distortion force is removed. There is, of course, a limit at which the stress value of elasticity ceases and this is known as the elastic limit.

Hardness: the ability of a metal to resist indentation. Relative hardness of metal is determined by its ability to scratch other metals.

Thermal Conductivity: this is the ability of a metal to transmit heat throughout its mass. This property, which is not the same in all metals, varies within a wide limit and is of great importance to the welder. In welding metal of high thermal conductivity such as copper, it is necessary to use an oversize torch. Conductivity, expansion and contraction are closely related. If a metal leads the heat away from the torch where the weld is taking place, the heated area will become much larger; consequently, expansion and contraction will increase.

Specific Heat: the amount of heat (measure in calories) absorbed by 1 gram of metal when its temperature rises through 1 degree centigrade, or released when it falls through 1 degree centigrade, is called the specific heat of that metal. A metal having a low melting point but relatively high specific heat may require as much heat to bring it to its point of fusion as a metal of high melting point and low specific heat.

Elongation: after a bar under tensile stress has passed its elastic limit, it begins to be permanently elongated in the direction of the pull. The increase in length divided by the original length is the percentage of elongation.

Melting Point: is the temperature at which a metal will change from a solid to a liquid state.

Annealing: a heating and cooling operation which will remove hardness and strains from certain metals before forming. It induces softness and modifies the grain of a metal.

Hardening: hardness is obtained by heating a metal to 760 degrees centigrade or higher (depending on the composition of the metal), then cooling rapidly; e.g., by plunging it into a liquid bath.

Case-Hardening: case-hardening of a metal is accomplished by carbonizing and consequent hardening the surface of the metal by a suitable heat treatment.

Normalizing: heat metal to about 27°C above the upper critical temperature (dull red or approximately 700°C for mild steel) and allow to cool in still air. This returns a hardened iron alloy to a ductile state.

WELDING HIGH STRENGTH STEELS

High-strength steels are used in machinery and equipment when increased tensile strength and other mechanical and physical properties are needed. Carbon is the most common alloying element used to improve strength in steels. Carbon steels fall into three major categories:

Low-carbon steels: contain from 0.15 to 1.30 per cent carbon: They are commonly called mild steels, Mild steels can be formed, sheared, bent and holes can be punched in them with relative ease. All the operation can be done without heating. Welding is also easy.

Mild steel doesn't contain enough carbon to harden appreciably, even if the welds are cooled quickly. There is practically unlimited choice of welding electrodes, and high speed automatic or semi-automatic welding processes. Mild steel has good ductility: It can stand bending, stretching and twisting, without breaking or cracking. Mild steel is mass-produced in the larger, most-efficient steel furnaces, making the least expensive grade of steel.

Medium-carbon steels: contain 0.30 to 0.45 per cent carbon, with no other element in amounts high enough to appreciably affect the properties of the steel. Steels in this category are used in machinery where their greater strength is required. Hitching members on cultivators, diskers, plows, and other similar implements, are quite often made from medium-carbon steels.

These steels have enough carbon in them to cause hardening and embrittlement if the steel is heated above a cherry red color and cooled quickly. Welds made on these steels will have a hardened zone at the fusion line, if the base metal absorbs the heat from the weld fast enough to cause hardening.

Welds can be made on this grade of steel if high amperages and slow travel speeds are used to heat a large volume of the base metal when making the weld.

This procedure slows down the cooling of the weld enough to avoid hardening. Some welding processes used in manufacture can achieve this requirement. But, on the farm, it is much safer and more reliable to preheat the base metal, and maintain the preheat temperature during the weld. Preheating slows down the cooling rate of the weld zone enough to prevent any hardening.

High-Carbon steels: contain over 0.45 per cent carbon. Steels containing 0.80 per cent carbon are used for many tillage tools, such as cultivator sweeps, plowshares, and springs. Most of these tools have been heat-treated to improve their strength and hardness. Other steels in this category are used for machinery parts, such as front-wheel spindles, forged-steel crankshafts, axles, and other similar parts that require high-strength steels.

High carbon steels require preheating to be welded. There are a number of problems that can be encountered if the correct, or high enough, preheat is not used.

. Cracking of the weld bead. The cracks may be across the bead through the center of the bead, or just under the surface of the bead and not visible.

. Porosity in the weld metal.

. Excessive hardening of the parent metal.

. Cracking of the parent metal. (See Diagram 1, 2 and 3).

Another problem encountered when preheat is used on heat-treated steels is this: excessive softening of the parent metal.

Alloy steels are a combination of alloying elemnts. The principal advantage of alloy steels is their ability to respond to heat treatment. Each alloying element gives special properties to alloy steel.

ALLOYING ELEMENTS

Carbon: hardness and increased tensile strength.

Chromium: great hardness and wear resistance. In percentages from 12 to 30 per cent, it provides corrosion resistance. All grades of stainless steel contain chromium.

Nickel: strength without loss of ductility, increased hardening ability, and fine grain size in steel. All but one type of stainless steel contain nickel but in lower percentages than the chromium. One of the most common grades of stainless steel is No. 308. It contains approximately 18 per cent chromium and 8 per cent nickel.

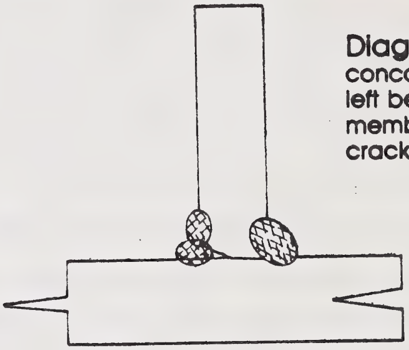


Diagram 1. The thin concave fillit on the left between two rigid members is likely to crack.

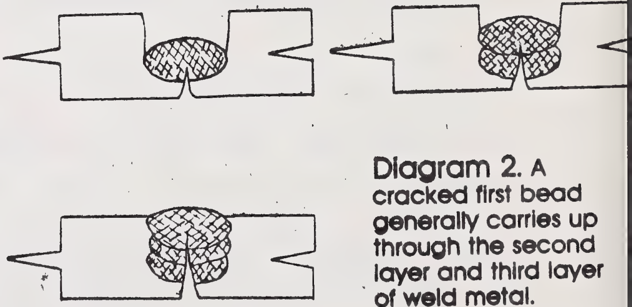


Diagram 2. A cracked first bead generally carries up through the second layer and third layer of weld metal.

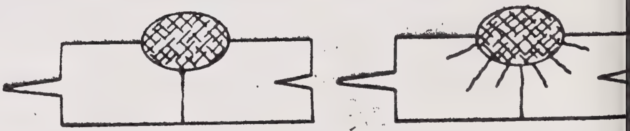


Diagram 3. An under bead crack and radial cracks in the parent metal.

Manganese: increases toughness of steel and hardening ability, and work hardens. Steels that contain over 12 per cent manganese are used where abrasive and impact wear are severe. This grade of steel is nonmagnetic, and can be identified by checking with a magnet. In small percentages up to 0.80 per cent, it is used as a scavenger to counteract the harmful effects of sulphur. Manganese is also an inexpensive element.

Vanadium: high elastic and tensile strength, and shock resistance (good impact strength). Also, promotes hardening ability and has fine grain size. Ball bearings contain vanadium. Good-quality hand tools are made from chromium vanadium steels: chromium for hardness and wear resistance; vanadium for high elastic and tensile strength, fine grain and shock resistance.

Tungsten: hardness at high temperatures. Godd-quality drills, for example, contain tungsten, Even when the cutting edge get shot, it will hold its edge. Lathe tools and milling cutters are also made with tungsten steel, These steels are called HSS (high speed steels).

Tungsten also has good thermal and electrical conductivity, almost as good as aluminum. Good-quality ignition breaker points contain tungsten for hardness at high temperatures and good electrical conductivity. That is why they are so difficult, or impossible, to clean with a file. You have to use emery cloth or some other abrasive material to clean them.

Cobalt: high strength and hardness at high temperatures. A base for some nonferrous hard-surfacing materials; for example, "stelite", which is used for surfacing exhaust valves.

Molybdenum: adds toughness to steel and maintains hardness and strength at high temperatures. Good-quality hacksaw blades are made with molybdnum steel.

Silicon: heat and acid resistance. Silicon is used in exhaust valves. Transformer steel: The type used in electric motors, generators, ignition coils and welders is a very low-carbon steel with silicon added to resist permanent magnetism.

Copper: improves atomospheric corrosion resistance and strength. Most carbon and alloy steels come under standards set up by the Society of Automotive Engineers (SAE) and the American iron and Steel Institute (AISI). They can be identified by a number system. For example, SAE number 5160 alloy steel, which is commonly used for shanks on heavy-duty cultivators. The chemical composition can be identified this way:

. The first digit, 5 X X X, indicates the type of steel. The number 5 is a chromium steel.

. The second digit, X 1 X X, indicates the approximate percentage of the predominant alloy. This alloy contains areound 1.5 per cent chromium.

. The last two digits in a four-digit number, or the last three of a five-digit number, indicate the approximate percentage of carbon in one-hundreths of one percent; for example X X 60. This alloy contains approximately 0.60 per cent carbon. Plain carbon steels start with the digits 10 X X. The last two or three digits indicate the percentage of carbon in one-hundreths of a per cent; for example, 1080 steel contains 0.80 per cent carbon.

See the boxed list of SAE steel specifications below.

SAE STEEL SPECIFICATIONS

Type of steel	Numerals (and digits)
Carbon steels	1×××
Plain carbon	10××
Free cutting (screw stock)	11××
Free cutting, manganese	×13××
High manganese	T13××
Nickel steels	2×××
0.50% nickel	20××
1.50% nickel	21××
3.50% nickel	23××
5.00% nickel	25××
Nickel chromium steels	3×××
1.25% nickel, 0.60% chromium	31××
1.75% nickel, 1.00% chromium	32××
3.50% nickel, 1.50% chromium	33××
3.00% nickel, 0.80% chromium	34××
Corrosion- and heat-resisting steels	30×××
Molybdenum steels	4×××
Chromium	41××
Chromium nickel	43××
Nickel	46×× and 48××
Chromium steels	5×××
Low chromium	51××
Medium chromium	52×××
Corrosion- and heat-resisting	51×××
Chromium-vanadium steels	6×××
Tungsten steels	7××× and 7××××
Silicon-manganese steels	9×××

Another group of high strength steels that are becoming very common in agricultural and industrial equipment are called low-alloy, high-tensile steels.

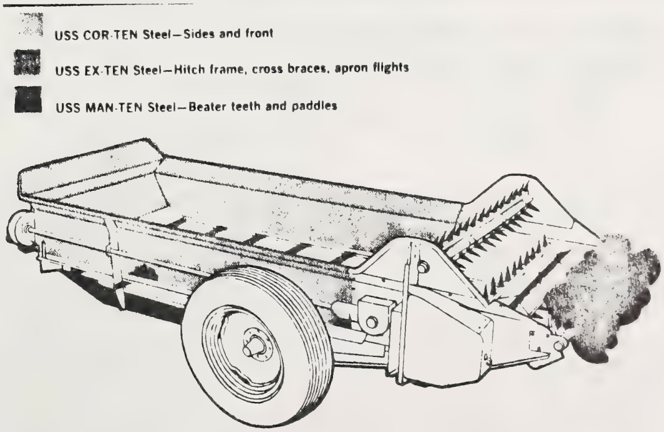
LOW-ALLOY, HIGH TENSILE STEELS

These steels usually contain a small percentage of carbon plus a very advantageous combination of other elements, such as manganese, copper, silicon, nickel and vanadium, in relatively small percentages. They offer high-yield strength (don't stretch easily), high ductility, high impact and endurance values, along with ease of forming good corrosion resistance and weldability.

Low-alloy, high-tensile steels are patented by various steel companies. For example, USS (U,S, Steel Co.) make:

"Cor-Ten": corrosion resistance five to eight times that of carbon steel plus 50 per cent extra strength. "Ex-Ten"; increased yield strength. "Tri-Ten": greater strength and toughness. "Man-Ten"; weight reduction due to increased strength, and toughness and corrosion resistance. "T1," "T1-type A" and "T1-type B": strength, ductility, reduction of weight and corrosion resistance. Each of these steels offers specific advantages. Manufacturers select on the basis of cost and desired properties.

Strength-to-weight ratio, corrosion resistance and relatively low cost, along with good weldability. are the main reasons these steels are becoming more and more common in the equipment we use.


░ USS COR-TEN Steel—Sides and front
▒ USS EX-TEN Steel—Hitch frame, cross braces, apron flights
█ USS MAN-TEN Steel—Beater teeth and paddles

TEST PROJECT

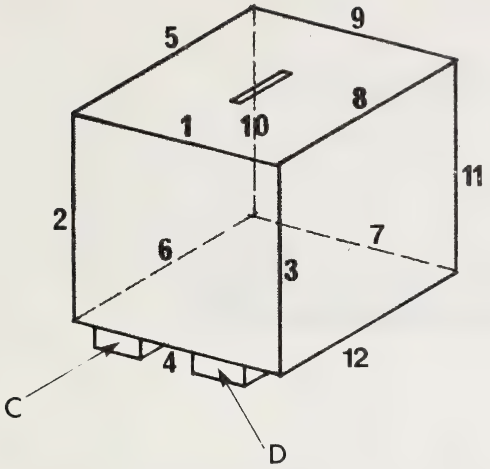
INSTRUCTIONS

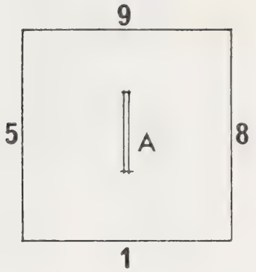
1. Complete the following test project according to the directions given.
2. Collect all materials required before hand from the instructors.
3. Plan your work carefully so that the box may be fixed in the positions indicated for each weld.
4. Use the oxy-acetylene torch and mild steel rod to tack pieces together before welding.
5. The Test Project must be completed and marked by the instructors before the student may go on to his own project work.

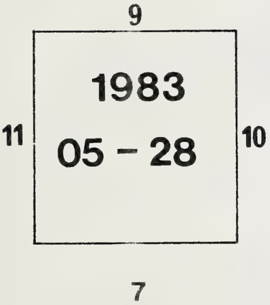
COMPLETE THE BOX USING THE FOLLOWING WELDS (SEE DIAGRAM)

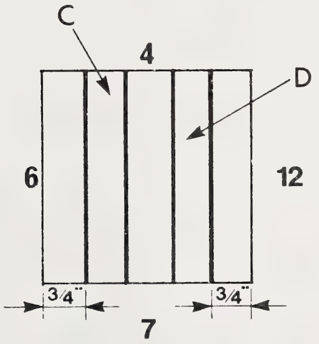
1. Arc weld with E6011 in flat position.
2. Arc weld with E6011 in vertical position
3. Arc weld with E6011 in horizontal position
4. Arc weld with E6011 in overhead position
5. Arc weld with E6013 in flat position
6. Arc weld with E6013 in horizontal position
7. Arc weld with E7018 in horizontal position
8. Arc weld with E7018 in overhead position
9. Oxy-Acetylene weld without filler rod in flat position
10. Oxy-Acetylene weld with steel rod in vertical position
11. Braze with coated rod in flat position
12. Braze with coated rod in horizontal position

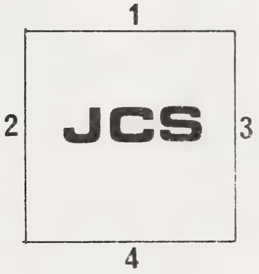
TEST PROJECT











MATERIALS LIST

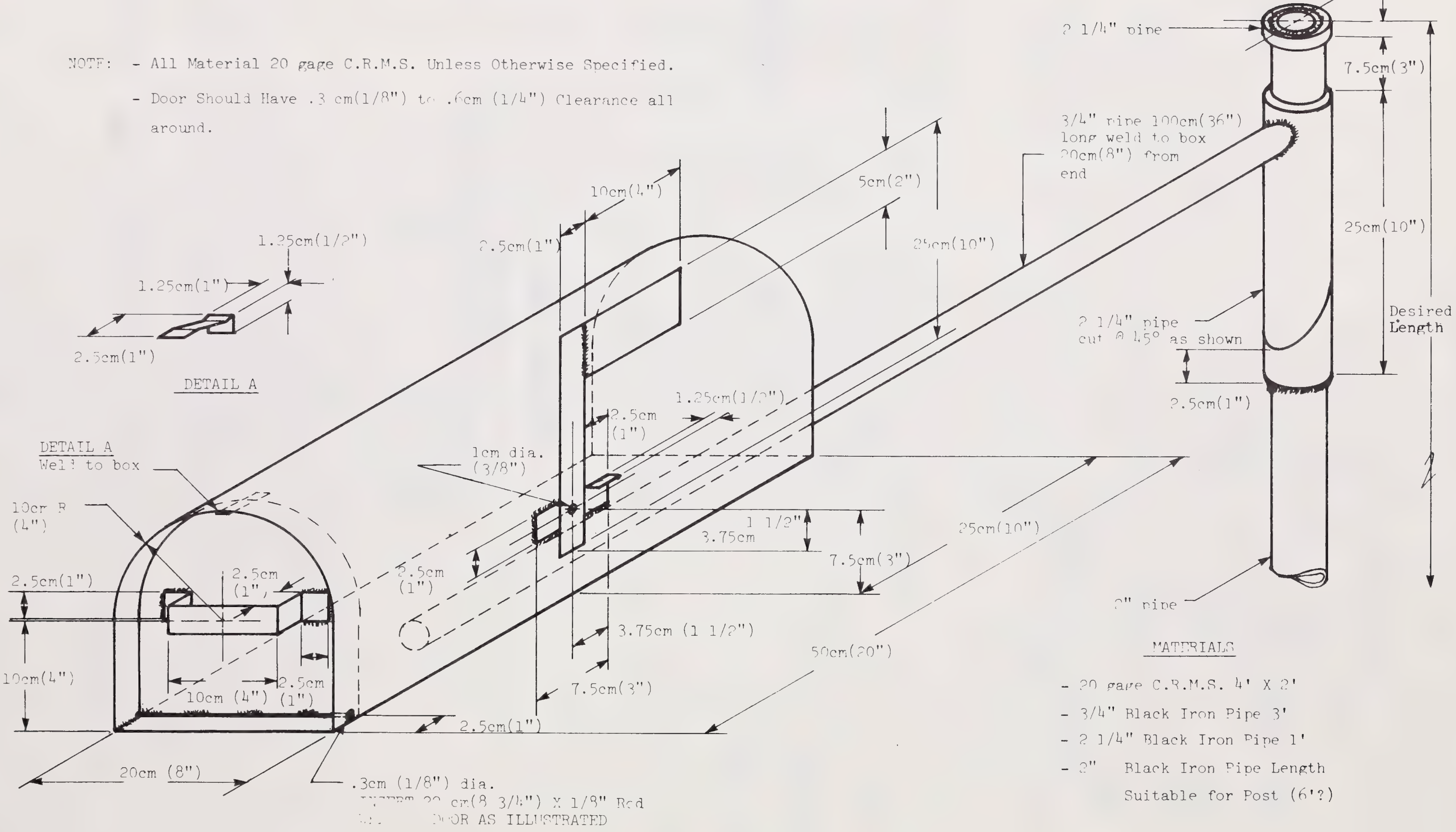
6 - 4" x 4" - 12 gage mild steel plate
2 - 1/2" x 3/4" x 5" mild steel stock
1 - bronze rod
1 - mild steel rod
2 - E7018 rods
8 - E6011 rods
6 - E6013 rods
1 - E7024 rod

A. Cut central coin slot 30 mm (1¼") long and 5.0 mm (0.20) wide with propane cutting torch.
B. Bead today's date in flat position with E6013 rod.
C. 1/2" x 3/4" stock cut flush with bottom using propane cutting torch. Fillet weld to bottom using E7024 in one pass per weld in flat position.
D. 1/2" x 3/4" stock cut flush with bottom using acetylene cutting torch. Fillet weld to bottom using E6013 in three passes per weld in horizontal position.
E. Put initials on front of bank by laying beads with high test rod in all positions: first initial - flat, second initial - vertical, third initial - overhead.

PROJECT 1. MAIL BOX

NOTE: - All Material 20 gage C.R.M.S. Unless Otherwise Specified.

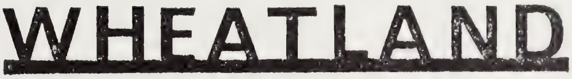
- Door Should Have .3 cm(1/8") to .6cm (1/4") Clearance all around.



MATERIALS

- 20 gage C.R.M.S. 4' X 2'
- 3/4" Black Iron Pipe 3'
- 2 1/4" Black Iron Pipe 1'
- 2" Black Iron Pipe Length Suitable for Post (6'?)

PROJECT #2 - NAMEPLATE



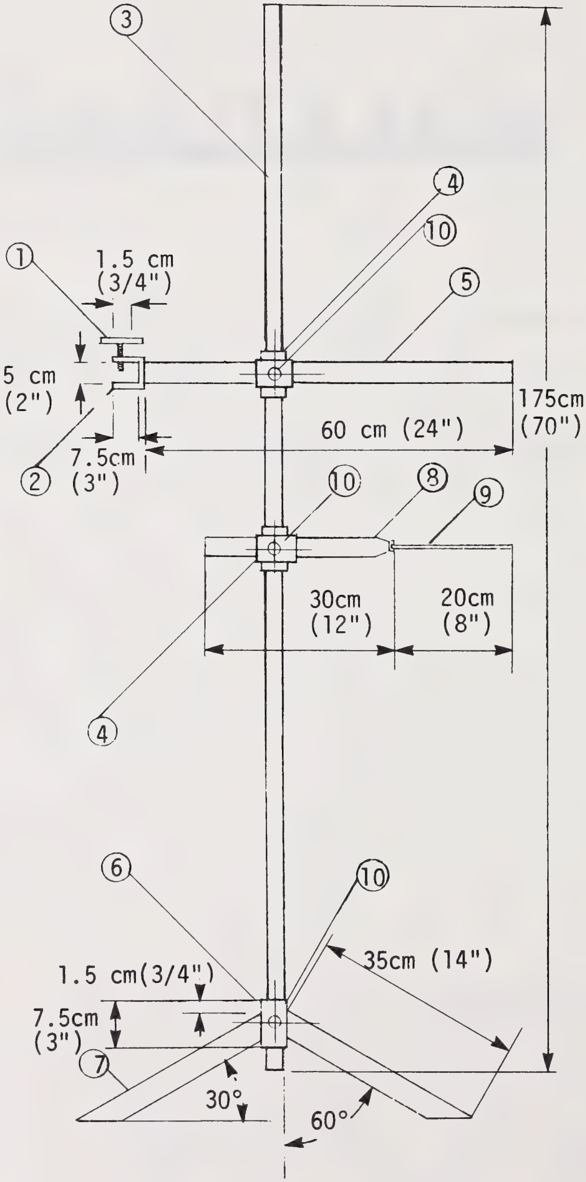
NOTE: Cut nameplate out of used grader blade using the propane cutting torch. (Do not cut letters off bar)

MATERIALS LIST: 1 - used grader blade of appropriate length.

PROJECT 3 - WELDING STAND

NOTES

1. Thumb screw - 1/2 U.N.C. 3" long thd. c/w Tee Handle & Nut.
2. Clamp 2" X 3/8" HRMS
3. Stand Pipe 1" std. Black Iron Pipe.
4. Adjustable Clamp - Consists of 2 - 1 1/4" x 3" long pieces of black iron pipe welded as shown @ 90°to one another.
5. Clamp pipe 1" std. black iron.
6. Stand pipe 1 1/4" std. black iron
7. Stand legs 2" X 3/8" H.R.M.S. 3 required
8. Table pipe 1" std. black iron
9. Table 6" X 3/8" H.R.M.S.
10. Thumb screw 1/2" U.N.C. 1 1/2" long thread c/w Tee Handle & Nut.



MATERIALS

1/2" UNC X 1 1/2"
LG Thumb Screw
5 required

1/2" UNC X 3" LG
Thumb Screw
1 required

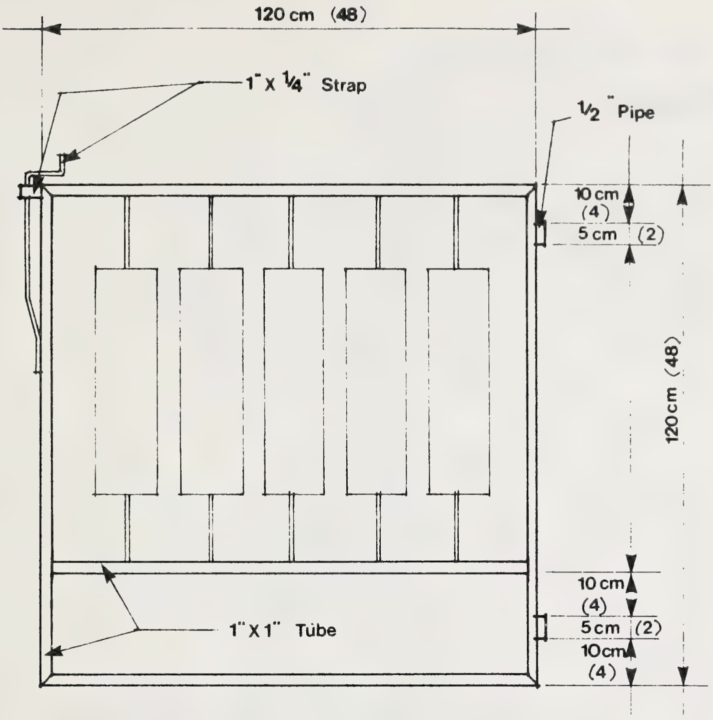
2" X 3/8" HRMS
strap 130 cm
(52")

1" black iron pipe
265cm (106")

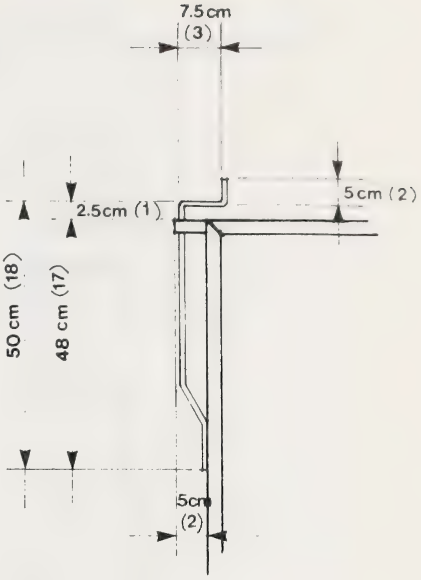
1 1/4" black iron
pipe ro cm (16")

6" X 3/8" HRMS
plate 20 cm (8")

PROJECT 4 - GATE



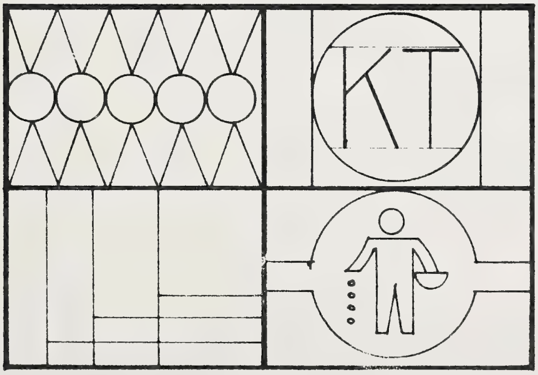
GATE



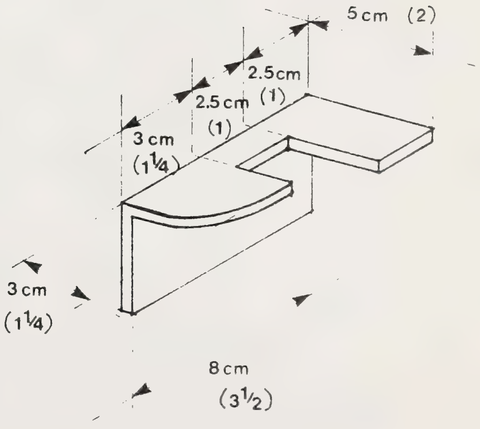
HANDLE DETAIL

MATERIAL

- 1" x 1" x 1/8 wall square tube 600 cm (20)
- 1/2" black iron pipe 10 cm (4)
- 1/4" x 1" strap 76 cm (28)
- 2" x 2" x 1/4" angle 8 cm (3½)



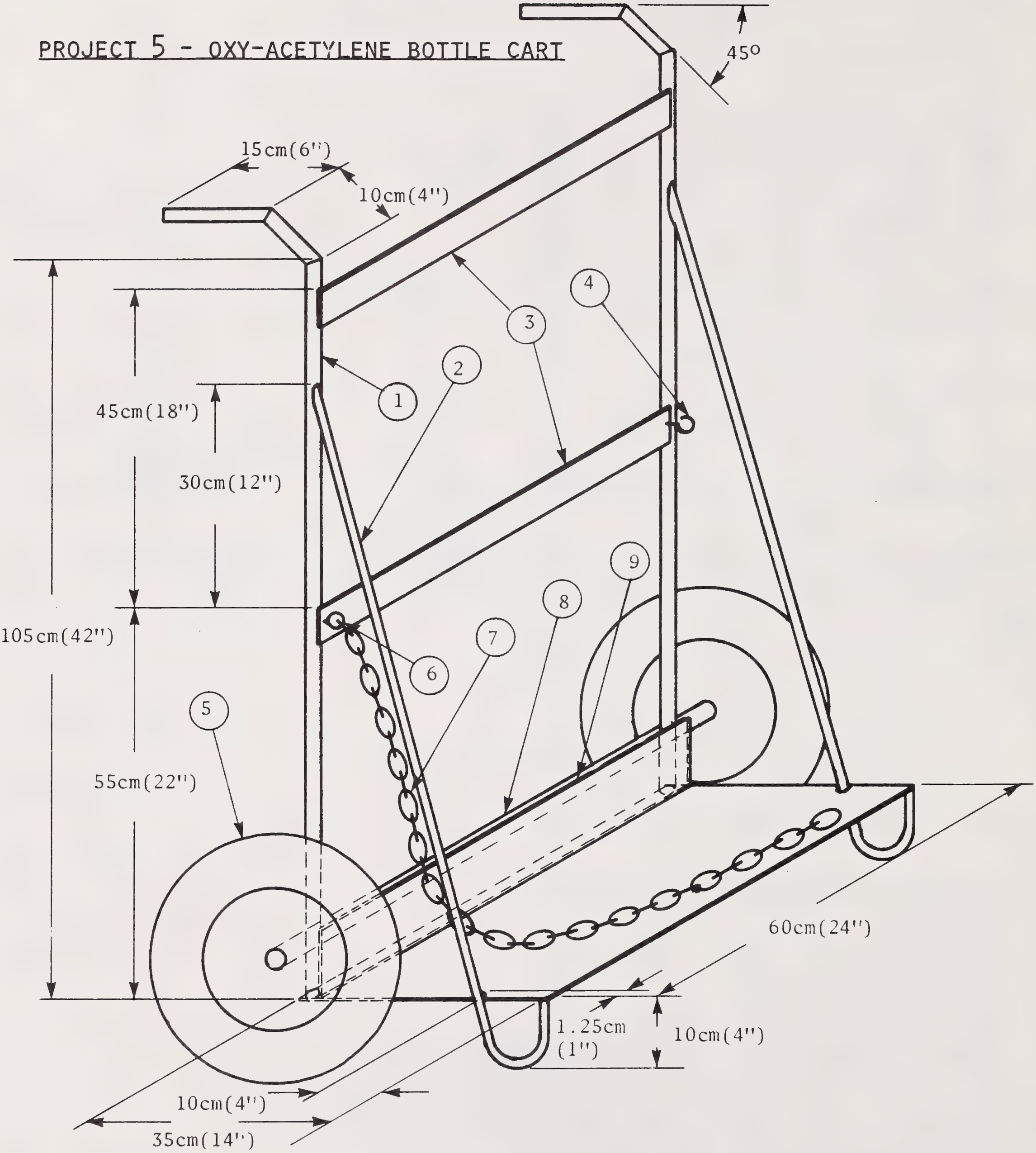
POSSIBLE DESIGNS FOR GATE INTERIOR



LATCH DETAIL

NOTE: ALL DIMENSIONS IN PARENTHESIS ARE IN INCHES

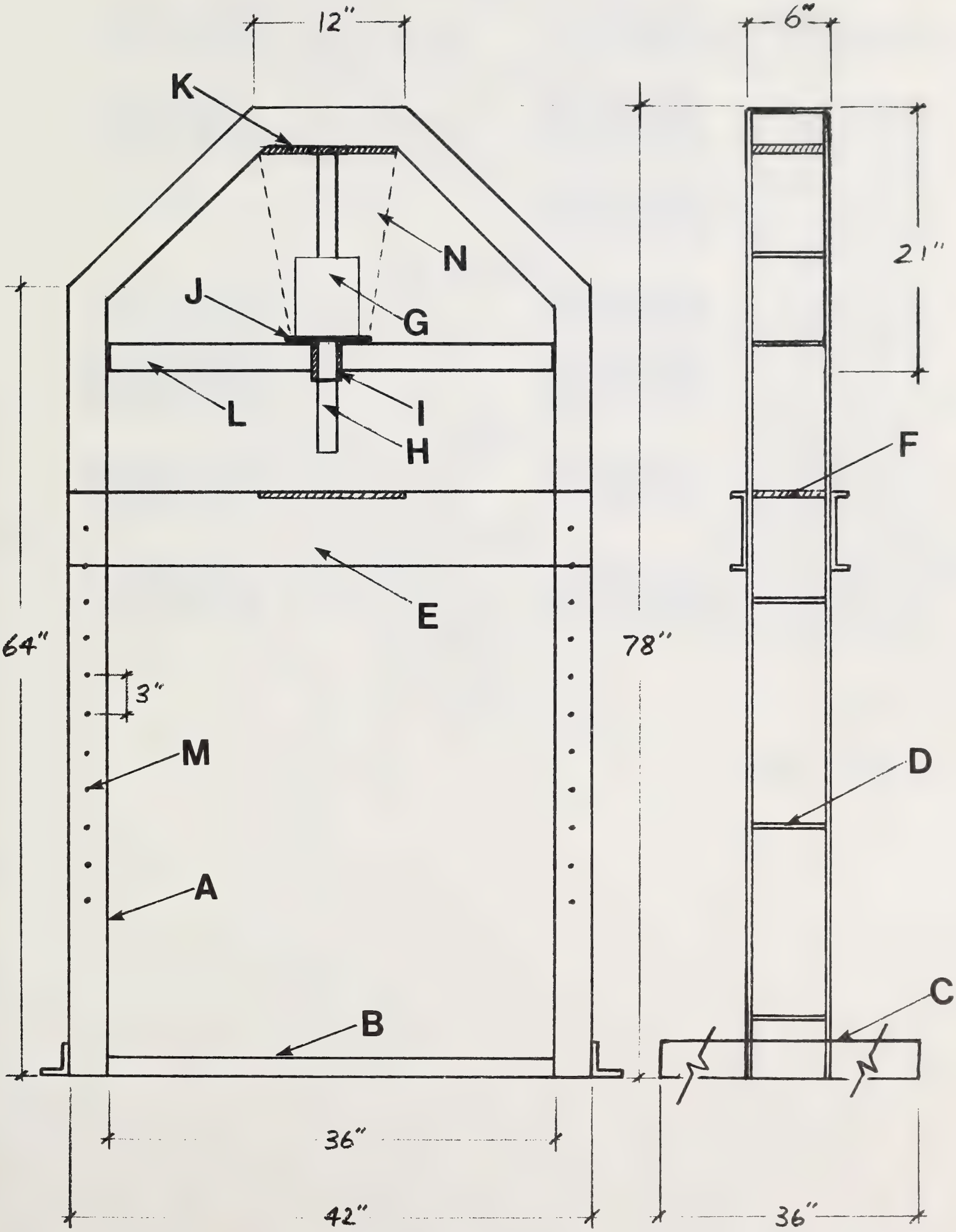
PROJECT 5 - OXY-ACETYLENE BOTTLE CART



MATERIALS & NOTES

1. 3/4" black iron pipe 260cm(104")
2. 1/2" hot rolled mild steel rod 240 cm (104")
3. 1/4" X 2" hot rolled mild steel strap.
4. 3/8" eye bolt (eye open) 1 required
5. Tires & rims c/w bearings 2 required
6. 3/8" eye bolt (eye closed) 1 required
7. 1/4" chain 142 cm (56")
8. Cold rolled shaft to fit wheels (92 cm (36")
9. 1/8" plate for back & bottom 46cm X 61 cm (18" X 24")

20 TON HYDRAULIC PRESS



PRESS - MATERIALS LIST

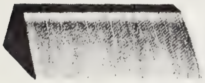
A. PRESS MAIN FRAME	3" x 1/2" FLAT IRON 4 pieces, each 104" long required
B. PRESS BASE SPREADERS	1 1/4" x 1 1/4" ANGLE IRON 2 pieces, each 42" long required
C. PRESS BASE	2" x 2" ANGLE IRON 2 pieces, each 36" long required
D. PRESS MAIN FRAME SPACERS	5" x 3" x 1/2" FLAT IRON 8 required
E. PRESS BED	6" x 5/16" WEB CHANNEL IRON 2 pieces, each 42" long required
F. PRESS BED PLATE	6" x 14" x 1/2" FLAT IRON
G. JACK	
H. PUSH ROD	1 1/2" DIAMETER X 16" LONG SHAFT
I. 1 1/2" BUSING	
J. JACK BASE PLATE	6" x 6" x 1/2" FLAT IRON
K. JACK HEADER PLATE	6" x 10" x 1/2" FLAT IRON
L. BUSHING SUPPORT	2" x 6" CHANNEL IRON 1 piece, 36" long
M. HOLES	1/2" DIAMETER
N. RETURN SPRINGS	

Correct Cutting Techniques

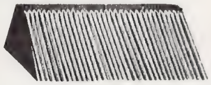
PERFECT CUT
shows regular surface with slightly sloping drag lines. Surface can be used for many purposes without machining.

PRODUCTION CUT
has moderately sloping drag lines and reasonably smooth surface. This type represents best combination of quality and economy.

WHAT TO LOOK FOR IN BEVEL CUTTING

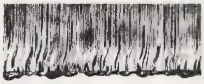


GOOD QUALITY
is shown by excellent top edge and extremely smooth cut face. The cut part is dimensionally accurate.



POOR QUALITY
Gouging is the most common fault, and is caused by either excess speed or too mild preheat flame.

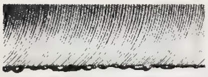
Common Cutting Faults



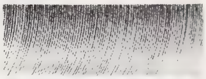
DIRTY TIP

DIRT
or scale in the tip will deflect oxygen stream and cause excess slag, pitting and undercutting.

CUTTING SPEED

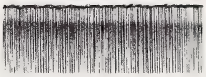


EXTREMELY FAST
Not enough time is allowed for slag to blow out of the kerf. Cut face is often slightly concave.



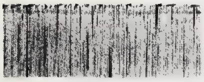
SLIGHTLY TOO FAST
makes drag lines incline backwards, but a "drop cut" is still attained. Quality is satisfactory for production work.

EXTREMELY SLOW
produces pressure marks which indicate too much oxygen for cutting conditions.

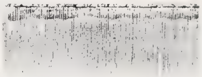


SLIGHTLY TOO SLOW
produces high quality cut, although there is some surface roughness caused by vertical drag lines.

TIP DISTANCE

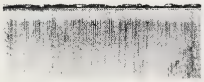


TOO CLOSE
Grooves and deep drag lines caused by unstable cutting action. Part of preheat cone burns inside kerf where normal gas expansion deflects oxygen cutting stream.

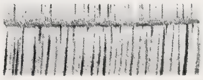


TOO HIGH
Top edge is beaded or rounded, cut face is not smooth and often is slightly beveled when preheat effectiveness is partially lost due to the tip being held too high. Cutting speed is reduced because of the danger of losing the cut.

GAS ADJUSTMENT



TOO HOT PREHEAT
Rounded top edge caused by too much preheat. Excess preheat does not increase cutting speed. It only wastes gases.



TOO MUCH CUTTING OXYGEN
Pressure marks are caused by too much cutting oxygen. Correct this fault by lowering cutting oxygen pressure, increasing speed, or using a smaller tip. As oxygen volume nears correct proportion, pressure marks appear closer to the bottom edge until they finally disappear.

N.L.C. - B.N.C.
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